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Introduction

Concepts

- Ecosystem: Self-regulatory, self-sustaining unit of biosphere with living community and physical environment interacting.
- Term coined by **A.G Tansley** in 1935.
- **Odum**: Biotic and abiotic components influence each other.
- Size varies: small pond to large forest or sea.
- Natural ecosystems: **Terrestrial** (forest, grassland, desert) and **Aquatic** (pond, lake, wetland, river, estuary).
- Man-made ecosystems: Crop fields, aquariums.

Memory Aids

- Ecosystem = Community + Environment interaction.
- Tansley = Ecosystem term origin.
- Two types: Terrestrial & Aquatic.

Quick Checkpoints

- What defines an ecosystem?
- Who coined the term ecosystem?
- Types of natural ecosystems?

Ecosystem Structure and Function

Concepts

- Every ecosystem has structural (components) and functional (processes) parts.
- Open system: Solar energy input; energy flow is **unidirectional** from producers to consumers.
- Components: **Abiotic** (non-living) and **Biotic** (living).

- **Cycling of matter** occurs between biotic and abiotic parts.
- Biotic: Producers (green plants), Consumers (herbivores, carnivores), Decomposers (microbes).
- Abiotic: Light, temperature, wind, soil, water.

Memory Aids

- Energy flows one way: Sun → Producers → Consumers.
- Biotic = Living; Abiotic = Non-living.
- Matter cycles between biotic and abiotic.

Quick Checkpoints

- What are the two main ecosystem components?
- How does energy flow in an ecosystem?
- Examples of biotic components?

Biotic Components of Ecosystem

Concepts

- **Producers (Autotrophs)**: Fix light energy, use inorganic substances, synthesize organic compounds.
- Convert solar energy to chemical energy.
- Include phytoplankton, some algae, submerged and marginal plants.
- **Consumers (Heterotrophs)**: Consume organic food, rearrange and utilize complex organic materials.
- Include zooplankton, free-swimming and bottom-dwelling animals.
- Types: Herbivores and Carnivores.
- **Decomposers (Reducers)**: Saprotrophs feeding on dead organisms and organic waste.
- Secrete enzymes to digest organic matter externally.
- Also called reducers and microconsumers.
- Include bacteria and fungi (moulds, mushrooms).

Memory Aids

- Producers = Energy converters.
- Consumers = Energy users.
- Decomposers = Nature's recyclers.

Quick Checkpoints

- Role of producers in ecosystem?
- Difference between herbivores and carnivores?
- Why are decomposers called reducers?

Abiotic Components of Ecosystem

Concepts

- **Light:** Source of solar energy for heating and photosynthesis.
- **Wind:** Controls weather, transpiration, pollination, and seed dispersal.
- **Soil:** Influences vegetation, flora, fauna via composition, temperature, water retention, aeration, minerals.
- **Temperature:** Varies globally; extreme values cause inactivity or death.
- **Water:** Essential for plants and animals; absorbed from soil or water bodies.

Memory Aids

- Light = Energy source.
- Wind = Weather and dispersal agent.
- Soil = Growth medium.
- Temperature = Life regulator.
- Water = Vital resource.

Quick Checkpoints

- Functions of light in ecosystem?
- How does wind affect ecosystems?
- Importance of soil composition?

Patterns of Ecosystem

Concepts

- Physical structure results from biotic-abiotic interactions.
- **Species composition:** Identification and count of species; varies by geography, climate.
- Maximum species diversity in tropical rainforests and coral reefs; minimum in deserts and arctic.
- **Stratification:** Vertical layers of species; e.g., 5-7 layers in tropical rainforests (emergent, canopy, understory, shrub, herb layers).
- Key functional aspects: **Productivity, decomposition, energy flow, nutrient cycling.**

Memory Aids

- Species composition = Diversity measure.
- Stratification = Vertical layering.
- Four functions = Ecosystem life processes.

Quick Checkpoints

- What affects species composition?
- Define stratification in ecosystems.
- Name four key ecosystem functions.

Productivity

Types and Definitions

- Productivity is the rate of biomass production per unit area over time by plants.
- Measured in energy ($\text{Kcal m}^{-2} \text{yr}^{-1}$) or weight ($\text{gm m}^{-2} \text{yr}^{-1}$).
- Depends on solar energy input, plant species, environment, nutrients, and photosynthetic capacity.
- Two main types: Primary productivity and Secondary productivity.

Primary Productivity

- Amount of organic matter produced by plants via photosynthesis per unit area and time.
- Includes Gross Primary Productivity (GPP): total organic matter produced.
- Net Primary Productivity (NPP): GPP minus energy used in plant respiration ($\text{NPP} = \text{GPP} - \text{R}$).
- NPP is the biomass available for herbivores and decomposers.
- Annual global NPP: ~170 billion tons dry weight; 55 billion tons from oceans, 115 billion tons from land.

Secondary Productivity

- Rate of food energy assimilation by consumers.
- Represents energy available at consumer level for transfer to next trophic level.

Memory Aids

- Productivity = Biomass production rate.
- GPP = Total photosynthesis output.
- NPP = GPP minus plant respiration.
- Secondary productivity = Consumer energy assimilation.

Quick Checkpoints

- What is the difference between GPP and NPP?
- How is productivity measured?
- What factors affect primary productivity?
- Define secondary productivity.
- Why is NPP important for heterotrophs?

Decomposition

Overview and Types

- Breakdown of complex organic matter (detritus) into inorganic substances (CO_2 , water, nutrients).
- Earthworms aid decomposition and soil aeration; called farmer's friend.
- Detritus includes dead leaves, barks, flowers, animal remains, and fecal matter.
- Key steps: fragmentation, leaching, catabolism, humification, mineralisation.
- Two types: above-ground (leaf litter, dried parts, animal remains) and below-ground (dead roots, underground animals).
- Decomposition rate depends on detritus composition and climate.
- Slower if detritus rich in lignin and chitin; faster if rich in nitrogen and water-soluble substances like sugars.

Memory Aids

- "Farmer's friend" = Earthworm helps decomposition and soil.
- Detritus = dead organic matter for decomposition.
- Slow decay = lignin + chitin; Fast decay = nitrogen + sugars.

Quick Checkpoints

- What is detritus?
- Types of detritus?
- Factors affecting decomposition rate?

Processes Involved in Decomposition

Key Processes

- **Fragmentation:** Detritus broken into smaller particles by detritivores (e.g., termites, earthworms), increasing surface area.
- **Catabolism:** Decomposers (bacteria, fungi) secrete enzymes to convert complex organic matter into simple soluble compounds and inorganic substances; some nutrients immobilised.
- **Leaching:** Soluble substances (sugars, nutrients) washed into deeper soil layers by water percolation.
- **Humification:** Formation of humus, a dark, colloidal, nutrient-rich, lignin and cellulose-rich substance resistant to microbial breakdown; maintains soil moisture and aeration.
- **Mineralisation:** Further breakdown of humus by microbes releasing inorganic nutrients; slow due to humus trapping and immobilisation.
- Factors affecting decomposition: temperature, moisture, pH.
- **Aerobiosis:** Oxygen is essential; aerobic conditions promote decomposition; anaerobic conditions slow it and cause detritus accumulation.

Memory Aids

- Fragmentation = detritivores break down particles.
- Catabolism = enzymes convert complex to simple.
- Leaching = nutrients washed down by water.
- Humus = stable, nutrient reservoir, colloidal.
- Mineralisation = humus to inorganic nutrients.
- Oxygen needed for decomposition.

Quick Checkpoints

- What role do detritivores play?
- Define catabolism in decomposition.
- What is humus and its importance?
- Why is oxygen essential for decomposition?

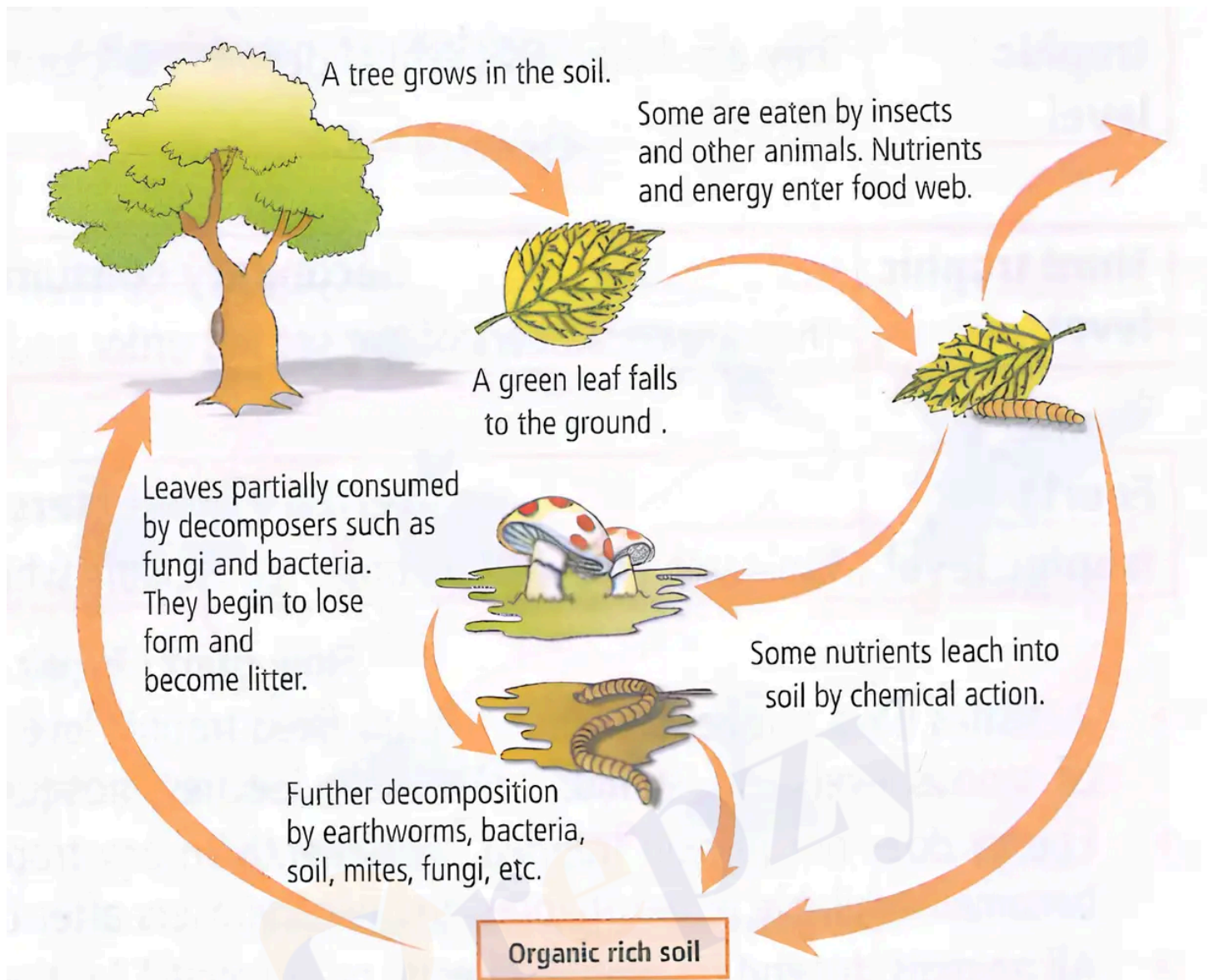


Fig.: Diagrammatic representation of decomposition cycle in terrestrial ecosystem

Decomposition Cycle

Cycle Explanation

- Tree produces green leaves in soil.
- Fallen leaves eaten by insects and animals, adding nutrients to food web.
- Nutrients leach into soil chemically.
- Fungi and bacteria partially decompose leaves into litter.
- Earthworms, bacteria, mites, fungi further decompose leaf material.
- Resulting organic-rich soil nourishes tree and supports new growth, completing cycle.

Memory Aids

- Leaves → eaten → leached → decomposed → soil enriched → tree growth.

Quick Checkpoints

- What happens to fallen leaves?
- Which organisms decompose leaf litter?
- How does decomposition support plant growth?

Energy Flow

Key Points

- Sun is the primary energy source for all ecosystems except deep sea hydro-thermal vents.
- Less than 50% of solar radiation is photosynthetically active radiation (PAR).
- Autotrophs capture only 2-10% of PAR to sustain life.
- Energy flow is unidirectional: Sun → Producers → Consumers, following the first law of thermodynamics.
- Ecosystems require constant energy input to maintain order, per the second law of thermodynamics.
- Producers: Green plants on land (herbaceous and woody) and phytoplankton, algae in aquatic ecosystems.

Memory Aids

- Energy flows one way: Sun to plants to animals.
- Only a small fraction of sunlight is usable energy.
- Producers start the energy chain.

Quick Checkpoints

- What is the main energy source for ecosystems?

- Define photosynthetically active radiation (PAR).
- Why is energy flow unidirectional?
- Who are producers in terrestrial and aquatic ecosystems?

Food Chain

Key Points

- Food chain: sequence of nutrient and energy transfer through organisms by eating.
- Involves repeated eating: each group eats and is eaten.
- Usually straight with 3-6 trophic levels; some organisms occupy multiple levels.
- Energy, biomass, and number of individuals decrease at higher trophic levels.
- Major energy loss as heat at each trophic level.
- Trophic level: position in food chain based on feeding method.
- Standing crop: biomass or number of organisms per unit area at a trophic level (dry weight preferred).
- Parasites feed across multiple trophic levels, not fixed.
- Energy passes to higher levels or decomposers after organism death.
- Lindeman's 10% law: only 10% energy transfers to next trophic level.
- Shorter food chains support more biomass efficiently.

First trophic level	Primary producers They are autotrophic or photosynthetic organisms found in an ecosystem which organic nutrients from inorganic raw materials with the help of solar radiation for themselves but also for heterotrophic organisms or primary consumers.	Organisms Phytoplankton, grass, trees
Second trophic level	Primary consumers (Herbivores) They are herbivores which depend on plants for nourishment and are consumers of first order.	Zooplankton, cow, grasshopper
Third trophic	Secondary consumers (Carnivores) They are consumers of the second order and are dependent on herbivores.	Birds, fishes, wolf
Fourth trophic	Secondary consumers (Carnivores) They are consumers of the second order and are dependent on herbivores.	Birds, fishes, wolf
Fourth trophic level	Tertiary consumers (Top carnivores) Top carnivores are last order consumers which are not preyed upon by other animals.	Eagle, Lion

Flow chart : Trophic levels in a food chain

Memory Aids

- Energy decreases by 90% at each trophic level.
- Standing crop = biomass at each level.
- Parasites span multiple levels.
- Short food chains are more efficient.

Quick Checkpoints

- What defines a trophic level?
- Explain Lindeman's 10% law.
- Why is energy lost at each trophic level?
- What is standing crop?
- How do parasites fit in food chains?

Types of Food Chain

Key Points

- Grazing Food Chain (GFC): Most common, involves predation at every step. Example: Grass → Goat → Man.
- Parasitic Food Chain (PFC): Starts with host, ends with parasite; involves parasites and scavengers.
- Detritus Food Chain (DFC): Begins with dead organic matter (detritus). Detritivores and decomposers (saprotrophs) feed on detritus. Example: Detritus → Earthworm → Sparrow → Falcon; with alternate path Frog → Snake → Peacock.

Memory Aids

- GFC = predator chain.
- PFC = parasite chain.
- DFC = decomposer chain.

Quick Checkpoints

- What organisms start each type of food chain?
- Which food chain involves parasites?
- Define saprotrophs.

Food Web

Key Points

- Food web: interconnected food chains forming multiple feeding connections.
- Provides alternative feeding paths, enhancing ecosystem stability.
- Example: Grass eaten by rabbit or mouse; mouse eaten by hawk directly or via snake.

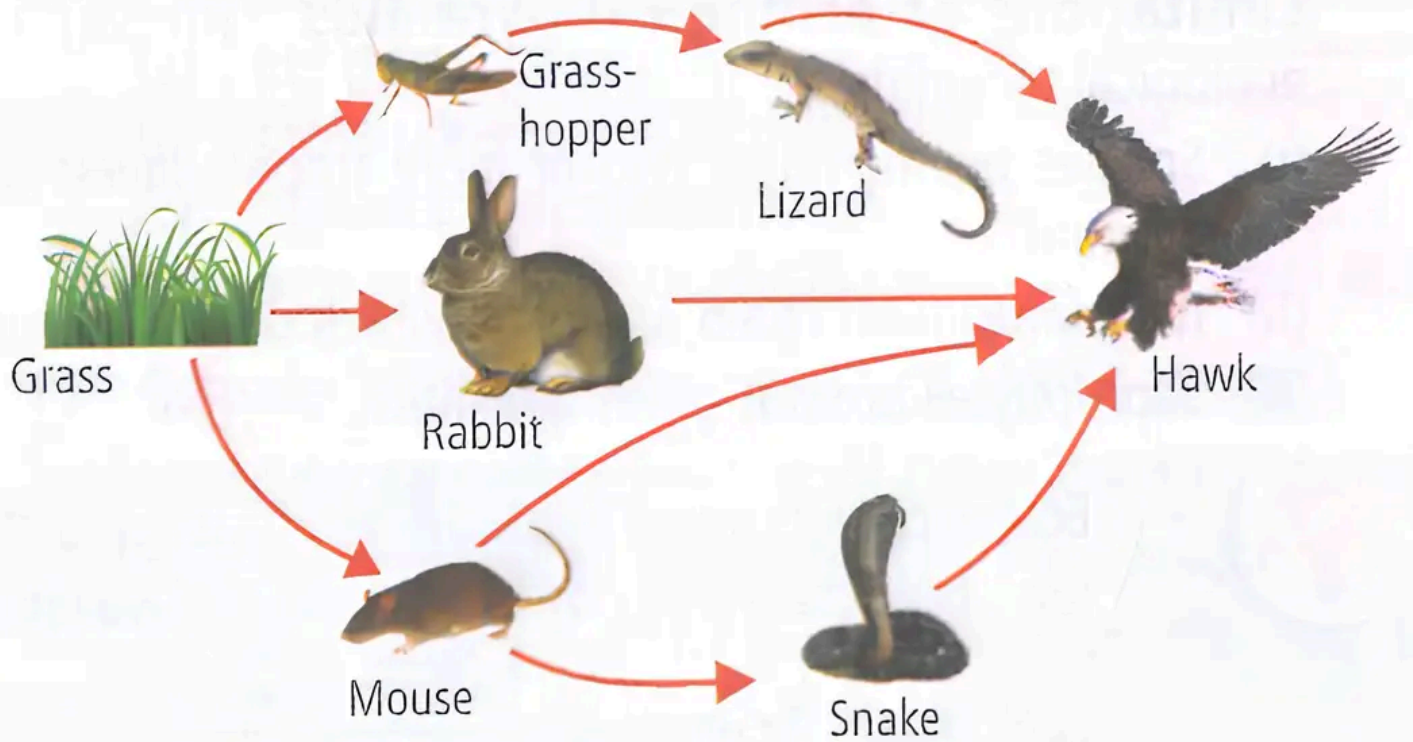


Fig.: Food web in a grassland ecosystem

Memory Aids

- Food web = network of food chains.
- Alternative feeding paths maintain balance.

Quick Checkpoints

- What is a food web?
- How does a food web differ from a food chain?
- Why are food webs important for ecosystems?

Ecological Pyramids

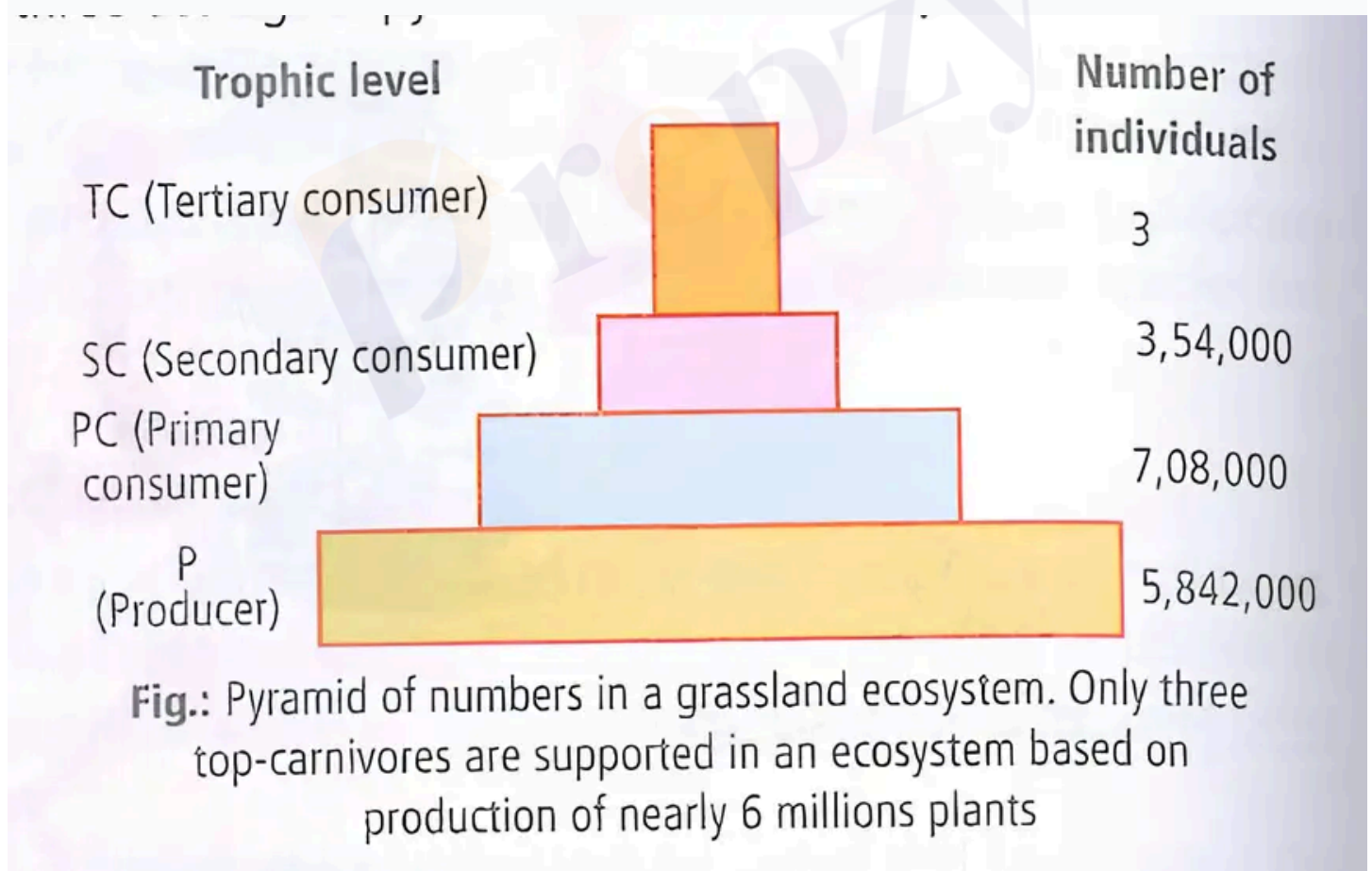
Definition and Basics

- Graphical representation of relationships between individuals at different trophic levels in a food chain.

- Measured in terms of number, biomass, or energy.
- Base represents producers; apex represents tertiary or top consumers.
- Developed by Charles Elton (1927), also called Eltonian pyramids.
- All organisms at a trophic level must be included for accurate calculations.
- Trophic level is functional, not species-specific; species can occupy multiple levels.

Types of Ecological Pyramids

- **Pyramid of Numbers:** Shows number of individuals per unit area at each trophic level; usually upright but can be inverted (e.g., parasitic food chains) or spindle-shaped (forest ecosystem).
- **Pyramid of Biomass:** Shows total biomass per unit area at each trophic level; upright in terrestrial habitats, inverted in aquatic ecosystems.
- **Pyramid of Energy:** Shows rate of energy flow/productivity per unit time and area; always upright due to energy loss at each level.



Memory Aids

- Eltonian pyramids = Ecological pyramids.

- Number pyramid: Upright except parasitic chains (inverted).
- Biomass pyramid: Upright on land, inverted in water.
- Energy pyramid: Always upright.

Quick Checkpoints

- What does the base and apex represent in ecological pyramids?
- Can a species occupy multiple trophic levels?
- What are the three main types of ecological pyramids?

Pyramid of Numbers

Characteristics and Examples

- Shows number of individual organisms per unit area at each trophic level.
- Usually upright in grassland and pond ecosystems.
- In parasitic food chains, pyramid is inverted due to increasing number of parasites at higher levels.
- Spindle-shaped in forest ecosystems.
- Example: Grassland ecosystem pyramid shows decreasing numbers from producers to tertiary consumers.

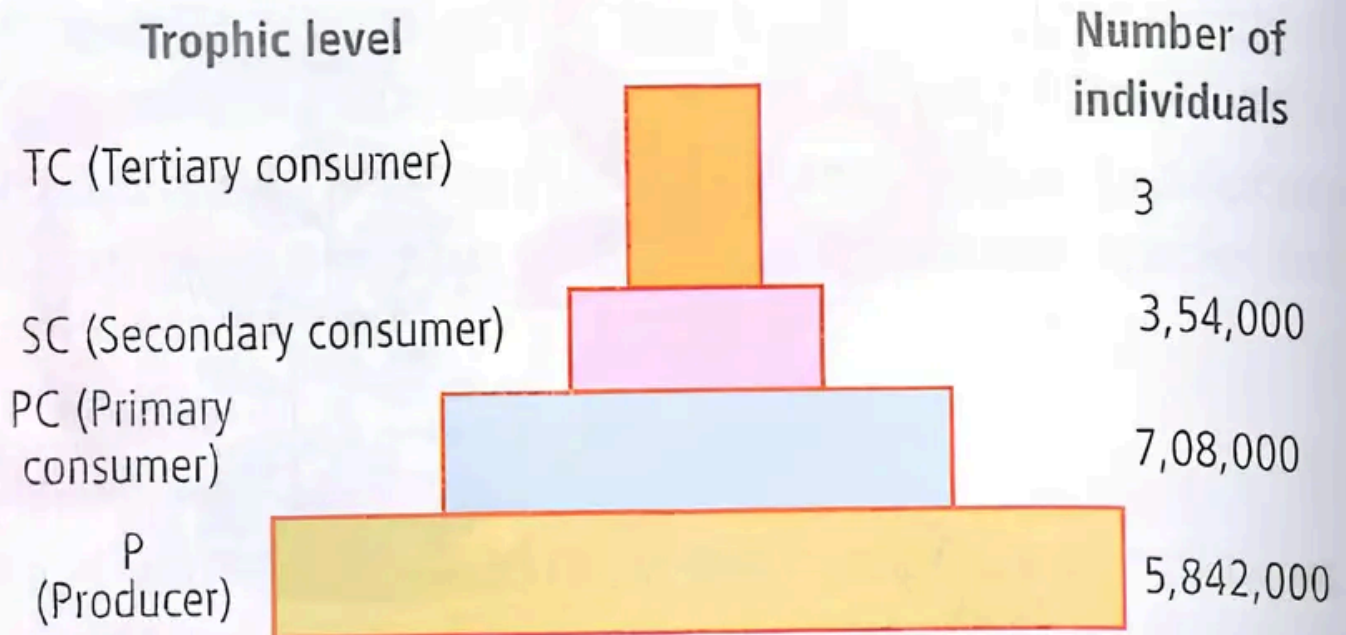


Fig.: Pyramid of numbers in a grassland ecosystem. Only three top-carnivores are supported in an ecosystem based on production of nearly 6 millions plants

Memory Aids

- Number pyramid = Count of individuals at each level.
- Inverted shape occurs in parasitic chains.
- Spindle shape in forests.

Quick Checkpoints

- What causes inversion in pyramid of numbers?
- How does the pyramid shape differ in forest ecosystems?
- Why do numbers decrease at higher trophic levels?

Pyramid of Biomass

Characteristics and Examples

- Shows total biomass per unit area at each trophic level.

- Upright in terrestrial habitats.
- Inverted in aquatic ecosystems due to small producer biomass (phytoplankton) supporting larger consumer biomass (zooplankton).
- Example: Dry weight decreases sharply from producers to tertiary consumers in terrestrial ecosystem.

Trophic level

**Dry weight
(kg m⁻²)**

TC

1.5

SC

11

PC

37

P

809

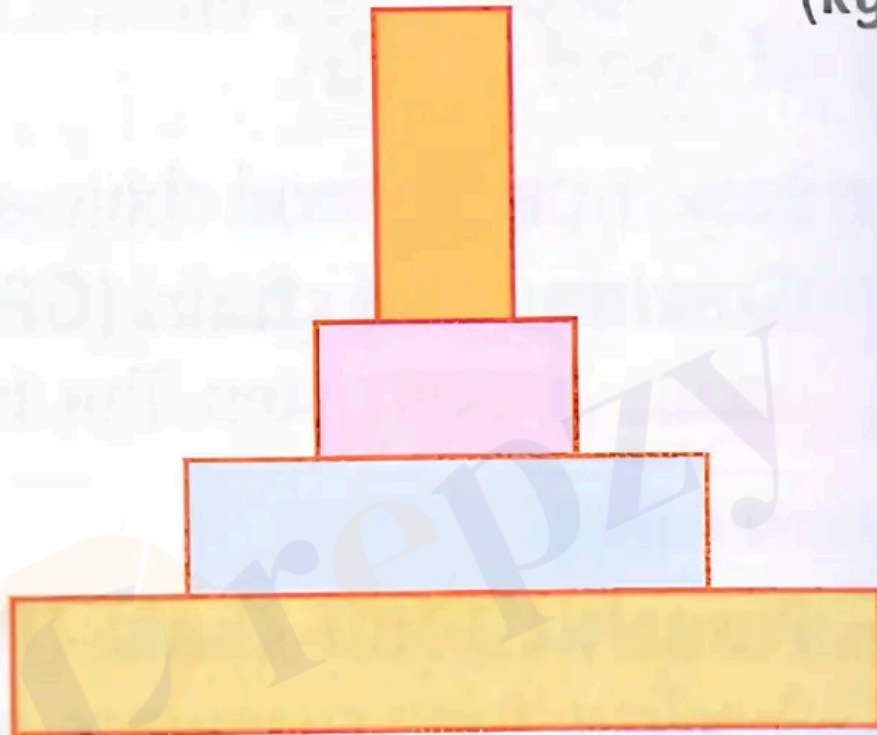


Fig.: Pyramid of biomass showing a sharp decrease in dry weight at higher trophic levels



Fig.: Inverted pyramid of biomass where a small standing crop of phytoplankton supports large standing crop of zooplankton

Memory Aids

- Biomass = Total mass of living organisms.
- Upright on land, inverted in water.
- Phytoplankton reproduce fast, supporting more zooplankton biomass.

Quick Checkpoints

- Why is the biomass pyramid inverted in aquatic ecosystems?
- How does biomass change from producers to consumers?
- What causes the sharp decrease in biomass at higher levels?

Pyramid of Energy

Characteristics and Examples

- Shows rate of energy flow or productivity per unit time and area at each trophic level.
- Always upright due to energy loss at each level.

- Energy decreases from producers to tertiary consumers.
- Example: Energy flow from sunlight to top consumers shows sharp decrease at each level.

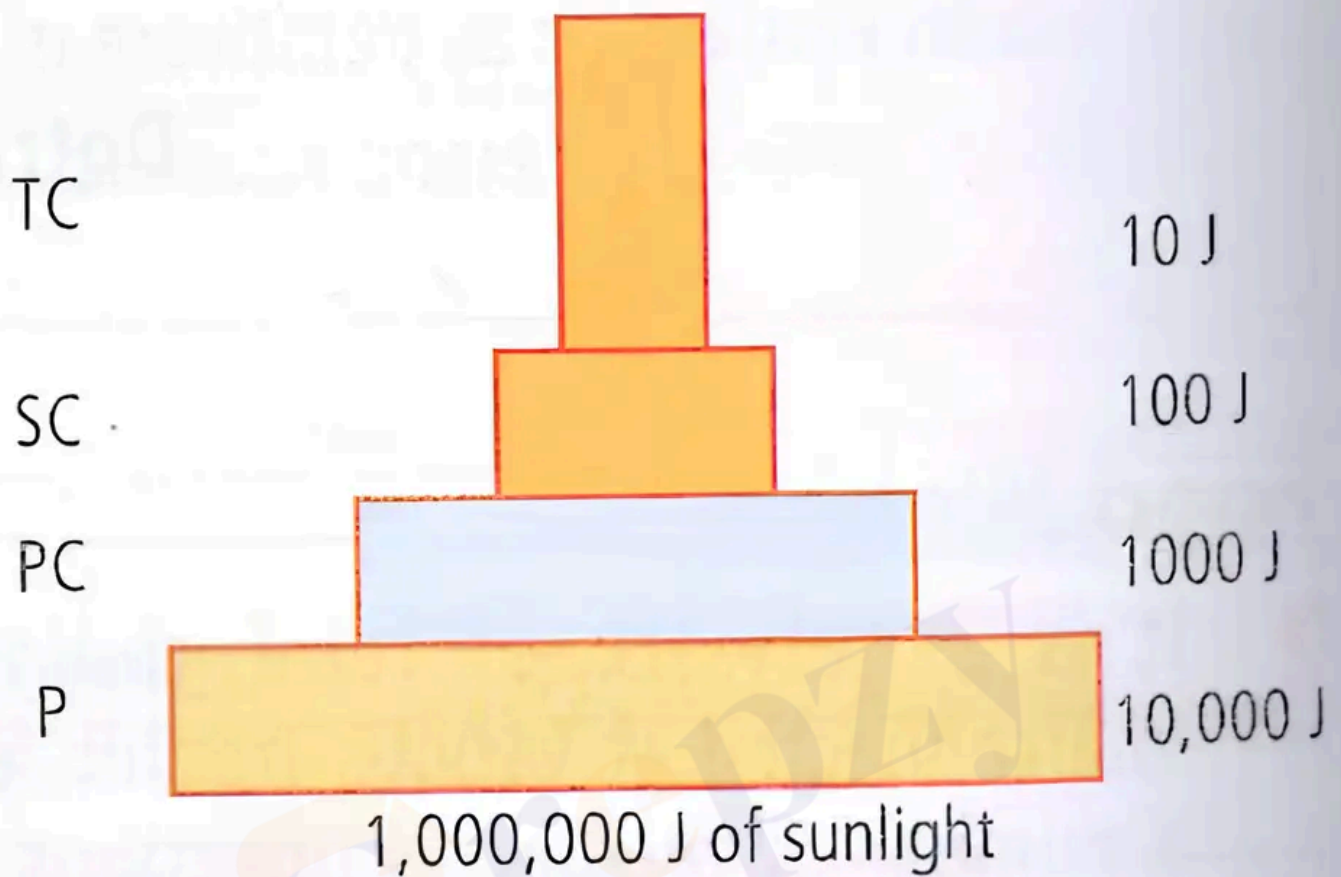


Fig.: An ideal pyramid of energy. Primary producers convert only 1% of the energy in the sunlight available to them into NPP

Memory Aids

- Energy pyramid always upright.
- Energy loss due to metabolism and heat.
- Only a small fraction of energy passes to next level.

Quick Checkpoints

- Why is the energy pyramid always upright?

- What causes energy loss at each trophic level?
- How much energy is typically transferred to the next level?

Limitations of Ecological Pyramids

Key Limitations

- Species occupying multiple trophic levels are not accounted for.
- Assumes a simple food chain, which is rare in nature.
- Saprophytes are excluded.

Memory Aids

- Multiple trophic levels ignored.
- Food chains are complex, not simple.
- No place for saprophytes.

Quick Checkpoints

- What are the main limitations of ecological pyramids?
- Why are saprophytes excluded?
- How does complexity of food chains affect pyramid accuracy?

Ecological Efficiency

Definitions and Types

- Percentage of energy converted into biomass at a trophic level over energy available at the lower level.
- Formula: Ecological efficiency = (Energy converted into biomass at trophic level / Energy present in biomass at lower trophic level) × 100
- **Assimilation Efficiency:** Percentage of food energy assimilated for body building from total food ingested.

- **Photosynthetic Efficiency:** Percentage of light energy converted into chemical energy by producers during photosynthesis (ratio of gross primary productivity to incident solar radiation).
- **Net Production Efficiency:** Percentage ratio of net primary productivity to gross primary productivity.

Memory Aids

- Efficiency = Energy converted ÷ Energy available × 100.
- Assimilation = Food energy used for growth.
- Photosynthetic = Light to chemical energy conversion.
- Net production = Net vs gross productivity.

Quick Checkpoints

- What is ecological efficiency?
- How is assimilation efficiency defined?
- What does photosynthetic efficiency measure?
- Difference between net and gross primary productivity?